Air Pollution and Human Health

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The Problem

Everyone agrees that air pollution is a bad thing - that it should be corrected now and that efforts should be made to prevent it in the future. However, not everyone has the same reason for this concern. Environmentalists worry about the long term effect on the atmosphere; engineers may think in terms of corrosion of buildings and other structures, such as bridges; transportation authorities see pollution as a cause of reduced visibility, both in the air and close to the ground; naturalists may identify air pollution as a threat to the existence of certain animal and plant species.

Despite all these good reasons for controlling air pollution the man in the street tends to think of it primarily as a hazard to health - his own health, that of his children, or that of unborn generations. Ironically, he is less apt to worry about the health of older people - the group who are known to suffer most from unusually high concentrations of pollutants.

The soiling of buildings or corrosion of bridges can be assessed in engineering or economic terms. It is possible to accept the fact that a building must be cleaned every 10 years or that we will budget for a 1/2% wasteage of bridge steel every year. It is much harder to accept this kind of approach where human health is concerned. We cannot say that we will allow "X" per cent of extra deaths this year, rather than spend additional money on pollution controls.

This is the reason why air quality standards are set at such low figures. When we say that the average amount of a substance in the air should not exceed 10 micrograms per cubic metre of air (this could represent as little as one part of the substance per billion parts of air), it is because we hope that this amount, when breathed for 24 hours a day, will not have a harmful effect, on anyone. These standerds are, in fact, an attempt to provide maximum protection for every member of society -- even the weakest and oldest.

Having said this, it must be admitted that it is unlikely that we will ever reach such a state of perfection. Even with the best controls that can be imagined, there will always be some individuals who are peculiarly sensitive to minute amounts of pollutants, and for whom absolute protection is almost impossible.

One aspect of pollution that is very difficult to evaluate is that of personal annoyance or discomfort. For example, a thousand people may be exposed to an odor which is generally acceptable and not ordinarily considered harmful, e.g. that of a bakery. Suppose now that one or two people find this odor so objectionable that it nauseates them and interferes with their enjoyment of life. How many people would agree that the bakery should be closed -- or even made to spend large sums of money in attempting to control the odor?

This simple example underlines the larger philosophical issues of whether any degree of pollution can be tolerated, whether there is ever a level of pollution which causes no significant effect. It also raises the question of how we are to assign values to differing degrees of risk or annoyance.

The "Dose" Concept

As in the case of any drug, the effect of an air pollutant depends partly on the amount to which the exposed person is subjected. It depends, too, on the period of time that the exposure continues. For this reason, it is important to keep in mind the principle of a "time-dose relationship". This phrase describes the fact that effects caused by air pollutants may depend not only on their absolute concentration in the air, but also on the amount of air breathed, the length of time it is breathed and the duration of time since the material was first breathed.

For example, we know that certain miners, when exposed to a given concentration of silica (silicon dioxide), may develop a disease called silicosis, but this only occurs if they have breathed a critical concentration of the material for a certain minimum number of years. It is also known that symptoms of the disease do not appear until a certain additional number of years - with or without additional exposure - have passed.

It has been suggested that another disease, asbestosis, caused by breathing asbestos fibres, may also occur years later in people who, at some time in the past, were exposed to a heavy concentration of that material. This seems to be true in a few instances where people lived close to asbestos mines or processing plants. However, no such effect has been noted in Canada - despite the fact that we are a major supplier of the material. Cases of asbestosis that have been identified in this country have been in people who were occupationally exposed, i.e. asbestos workers.

Concentration of Pollutants

The amount of a substance which exists in a given amount of air is its "concentration". We can describe this in terms of the weight of the substance for a known volume of air (e.g. 10 micrograms of lead in

a cubic metre of air).

In the case of gases or vapors, it is common to speak of volume of the material in a known volume of air, e.g. 1 part of sulphur dioxide (gas) per million parts of air (1 ppm). For sulphur dioxide, for example, 1 ppm would be equivalent to about 2,600 micrograms (millionths of a gram) per cubic metre of air. This is not a constant relationship but one that differs for each substance and depends on its molecular weight as well as on the temperature and pressure of the air.

Permissible Intake

How do we decide what concentration of a given substance can be breathed safely? To arrive at this we should know what amount of the pollutant produces an adverse effect, how much the person may be getting from other sources than air, e.g. in water and food, and how much air is breathed in a given time.

In the case of industrial workers it is common to speak in terms of an 8-hour average, since this is the time most people spend at their work. The amount of a material which it is safe to breathe for this time period is called the "threshold limit value (TLV)". TLV's are calculated for a large number of occupationally-encountered substances. By collecting information about workers who were exposed to excessive amounts, industrial hygienists first learned about the harmful effects of many chemicals. At the same time, they were learning what concentrations could be breathed safely over a man's whole working life.

The average person, during quiet breathing, breathes about 12 to 14 times a minute and takes in 500 cubic centimetres (cc) - about 1 pint - of air with each breath. If we take the higher figure of 14, then we can see that the average person takes in about 500 x 14 x 60 (min.) x 24 (hours) = 10,080,000 cc of air in 24 hours. This is approximately 10 cubic metres of air.

A man doing fairly strenuous work may breathe 20 times a minute and take in as much as 1,000 cc of air with each breath, so that his intake in an 8-hour working day would be 1,000 x 20 x 60 x 8 = 9,600,000 cc, which is again about 10 cubic metres of air.

If we assume that the air in the working environment contains some pollutant at a concentration of 2 milligrams per cubic metre of air, then the workman could take in up to 20 milligrams (10 x 2) of that substance during his 8-hour working day. Of course, it is unlikely that it would all remain in his lungs, since some is bound to be expired again. In this particular case, if we decided that an intake of 20 milligrams per day was a "safe" dose - one that has no adverse health effect, - then the TLV for that substance would be set at or below 2 milligrams per cubic metre of air (usually abbreviated as 2 mg/m^3).

We must also make allowance for the amount which will be breathed during hours away from work, when the workman will breathe about another 6 cubic metres of air. This will be air in which, presumably, the contaminant will be at a much lower concentration than in the working atmosphere. Suppose it were at one-tenth the concentration, i.e. 0.2 mg/m^3. His "off-work" exposure would then add about $6 \times 0.2 = 1.2$ milligrams to the 20 mg which he received while at work.

Whether this additional amount is to be considered significant will depend on how the particular substance is handled in the body. If it is something which is fully retained and builds up to a toxic level, it could be of some importance. On the other hand, if it is something that is rapidly detoxified or excreted from the body, it might be less important.

In the case of some pollutants there may be an additional contribution from other sources, e.g. food and water, chemicals handled in pursuing a hobby, household and garden pesticides, and so on. The fate of these in the body must also be considered. To mention lead again - for most people the amount consumed in food and water is 6 to 10 times as much as they breathe. However, of that which goes into the digestive system very little is absorbed, while much more of that which is breathed is retained in the body. This results in almost equal amounts being absorbed from the lungs and from the digestive system, although the amounts entering the two systems are quite different.

All of these factors must be considered in establishing safe levels, either for occupationally exposed workers or for the general population. Obviously, the level of exposure which we permit for the public will be less than that which the healthy industrial worker can tolerate.

Relationship Between TLV's and Community Air Quality Objectives

Although community air quality objectives will always be considerably lower, we cannot apply any constant factor to this relationship. A comparison of air quality objectives and TLV's in Ontario would reveal that the safety factor applied may be 2, 5, 10, or even 100 times, depending upon the substance in question.

A good example is that of sulphur dioxide (SO_2). The TLV which we use in industry is 5 parts of SO2 per million parts of air. At the community level, however, we require the 24-hour average to be at or below 0.1 ppm, i.e. 1/50th of the industrial level. This is a very low level of $S0_2$ to be concerned about, but the figure was chosen because some early studies suggested that the health of vulnerable people might be affected if a higher level were maintained for a prolonged period of time. There is now some question whether such a low concentration of $S0_2$ could have any harmful effect but until this is fully resolved most authorities will retain the low figure.

Mixed Pollutants

This brings us to another consideration - that of mixtures of pollutants. Studies or experiments with SO_2 alone have not shown any effect on health at 1.0 ppm (10 times our community standard) or even at somewhat higher concentrations. However, in situations where SO_2 was one of a mixture of pollutants - including very small "respirable particles" - there is some evidence that levels somewhere between 0.1 and 1.0 ppm could have some harmful effect on susceptible people over a long period of time.

The effect that has been most commonly reported is that people with chronic bronchitis tend to have an increase in their symptoms - cough, sputum production and shortness of breath. It must be emphasized that this has been noticed when the SO_2 content of the air was increased but is not necessarily due to SO_2. SO_2 is produced whenever fossil fuels - particularly coal and oil - are burned. The production of this gas is bound to increase in cold weather, and there is always the possibility that the cold air itself or some other pollutants are the main culprits.

What Kind of Health Effect?

Air pollution implies the introduction of harmful material into the body, either by direct contact - as with the skin - or through the respiratory system. We can also think of air pollution as affecting food and water, which may then be taken into the body by mouth.

Some of the effects which have been ascribed to air pollution are listed below (Appendix 11 lists some common air pollutants and their presumed effects):

(a) Damage to the lungs and other parts of the respiratory system

Experimentally, a number of common air pollutants are damaging to lung tissue or interfere with lung function in other ways. To produce these effects, however, it is usually necessary to employ concentrations of the substance much greater than are ever encountered in community air. This has given rise to speculation that mixtures of pollutants, as they occur in community air, may have a combined effect greater than that expected from individual types.

This seems to be particularly true for some gases, like sulphur dioxide, which seem to be much more harmful in the presence of moisture and fine particles than in their pure state.

In theory the fine particles adsorb the gas and then carry it down into contact with the lung tissue. This is the explanation given for the severe effect of air pollution "episodes", when disease and death result from concentrations of pollutants which, individually, would not be considered harmful.

An air pollution episode is defined as a period, usually of several days duration, during which stagnating air causes an accumulation of pollutants close to the earth's surface, where it can be breathed. In the past, such episodes have always occurred in association with cold, damp air, and at times of maximum fuel consumption for heating purposes.

The effect on lungs is not specific for this condition. People with advanced heart or lung disease are particularly susceptible. The result may be an aggravation of their existing condition, often leading to death.

This dramatic effect of major pollution episodes naturally leads to speculation about the damage which may result from breathing lesser concentrations of polluted air over many years. This is discussed below.

(b) Acute intoxication by poisonous substances

This is a rare event, but can follow an accident such as a wrecked railway tank car which releases dangerous amounts of ammonia, chlorine, nitric acid, or some other toxic material.

(c) Chronic intoxication resulting from the inhalation of small amounts of a toxic substance over a long period of time

This is most likely to occur in "occupational" exposures, and it is from the experience of industrial workers that most of our early information came. Now we are concerned about how much effect there could be on the public, i.e. people living in the vicinity of a plant which discharges toxic substances to the atmosphere.

The emission of lead from gasoline engine exhaust is another case in point. Lead tends to accumulate in the body. If a sufficient amount is retained, it may cause lead poisoning - a serious disease of the nervous system. Actually, the dose of lead acquired in this way is usually well below that required to produce any kind of symptoms. This is one reason why there is still lack of agreement on removal of lead from gasoline. The decision would be easier, were it not for the fact that removing lead may cause an increase in other exhaust gases.

(d) Allergic reaction to materials in the air

Plant pollens, such as ragweed, constitute the commonest form of air pollution which produces a recognizable effect, i.e. hay fever. Some chemical substances can also act as allergens or as substances which enhance the body's reaction to allergens. This is an area in which there is still much to learn. A few physicians believe that allergy is a common response to industrial chemicals, while most consider this an unusual cause.

(e) "Irritation" of eyes, nose, throat or skin

This is a common complaint when people are exposed to "photochemical smog" which results from the action of sunlight on automotive exhaust gases. The main products are compounds known as oxidants and aldehydes which can make the eyes water, make the throat feel sore and dry, and cause itchiness of the skin. This kind of smog is more common in southern cities, notably Los Angeles, but may also occur elsewhere with high concentrations of automotive exhaust gas and bright sunshine.

(f) Cancer

The mode of action of carcinogens (cancer-causing substances) is not yet fully understood, though more is being learned each year. We know that certain products of combustion, called polycyclic hydrocarbons, can produce cancer in test animals in the laboratory. Whether the minute amount of these chemicals that we breathe can have a similar effect on people is not fully established.

There is little hope of completely ridding city air of these substances so long as we burn coal, oil and other fossil fuels. Some people believe that these substances are responsible for the fact that lung cancer is more common in cities than in rural areas.

Similar substances also occur in cigarette smoke, and lung cancer is essentially a disease of cigarette smokers, occurring only rarely in non-smokers. If the polycyclic hydrocarbons are the cause of this disease, it is not difficult to see why smokers should be affected, as their form of "personal air pollution" is the most intensive form of pollution that can be experienced on a long term basis.

(g) Nuisance Effects

Many chemical substances have unpleasant odors at concentrations far below those at which a toxic effect could occur. These odors may give rise not only to annoyance but, in some cases, to severe psychological disturbance in those who are most offended by them.

A similar effect may be produced by some dusts. While some are intrinsically harmful, there are others which are biologically inert but which can be very annoying because of their soiling effect on materials, automobiles, laundry, etc.

(h) Noise Damage

Noise has been described as unwanted sound. This is gradually coming to be accepted as a form of air pollution. It has both physical and psychological effects, ranging from loss of hearing, to sleep deprivation and general irritation. Some places have had anti-noise laws for years but, in most cases, they have been difficult to enforce because of imprecise methods of measuring and assessing the effect.

Better methods of regulating this hazard are gradually being formulated.

In summary, pollutants may be classed as systemic (general) poisons, pulmonary or other irritants, allergens, carcinogens, odors, or physical agents (such as noise). There is great variability in the degree of damage that they may cause. The object of a control program should be to identify those agents which cause appreciable harm and to concentrate first on regulating the ones which pose the greatest threat.

Research Methods

How do we study the effects of air pollution?

If it were possible to give a person a certain "dose" of air pollution and then record his reaction to it, it might be easier to say what the effects on human health can be. In practice, this is true of only a very few pollutants, because most occur in community air in doses or concentrations too small to give an immediate, observable effect.

In fact, the result that we are mainly concerned with is that from breathing polluted air for a prolonged period (10 years? 20 years?). The obvious difficulty is, not only that we have to wait 10 or 20 years to see the results but, when we do that, we then have only a very inexact idea of what the person has breathed in the interval.

However, there are a number of more helpful methods by which we can study the effects of air pollutants, such as

(a) observing the effects on people who are regularly exposed to known pollutants in their occupation

This can give very good information about how the pollutant affects the body but here, too, the concentration is usually many times higher inside the plant than outside in the community air. It is not necessarily true that a small amount of something breathed over a long period of time will have the same effect as a large amount over a short period of time.

(b) studying the effects of major air pollution "episodes"

There have been a few episodes in the past - mainly in London and New York - when heavy "smog" (smoke and fog) persisted for several days combined with low temperatures and absence of air movement. During such episodes many people died - undoubtedly as a result of the smog.

Those who succumbed were almost all very old or people with chronic disease of lungs or circulatory system. Some small premature babies were also victims.

Unfortunately, these episodes have mostly been studied in retrospect and the exact nature of the pollution was not known. It can be assumed that it was basically similar to the usual pollution of the cities affected though at greatly increased levels, but even this information is not too helpful in teaching us about long-term effects of ordinary day-to-day pollution.

(c) laboratory experiments

Research workers have exposed small animals, monkeys, and even human volunteers to measured amounts of pollutants in an attempt to determine their effect. As mentioned earlier, the amount of a substance which will produce an effect in the laboratory is usually large in comparison with the amount in community air.

The kind of effects noted are symptoms - such as cough, pain, shortness of breath - or objective changes such as damage to tissue cells, decrease in respiratory function, or changes in the biochemistry of the blood. Animal studies add to our knowledge of how pollutants work, but the findings cannot be directly translated to humans. The studies on humans can, of course, only give information on short-term effects.

(d) epidemiological studies

Our best information about the long-term health effects of air pollution comes from comparisons between communities or groups of people, or of the same group under different conditions. For such a comparison to be valid, the two groups must be as similar as possible with respect to sex and age distribution, economic status, smoking habits, and any other factors which might influence the findings.

In practice, because the effects are usually difficult to measure, the larger the number of people studied, the more reliable the conclusions are likely to be.

Another way of getting information is to select a group of people who have a condition which is liable to be affected by air pollution - such as asthma or bronchitis - and to observe their reaction to changes in the pollution level of their environment.

Usually such people are requested to keep a diary in which they record "attacks" or increases in their usual symptoms. This information is then collected and compared with known changes in the levels of various pollutants. At the same time, it is important to note meteorological conditions as some symptoms may change in response to temperature, humidity, barometric pressure, or wind strength.

All in all, useful studies are obviously very difficult to achieve. Medical literature contains hundreds of articles on the health effects of air pollution, but only a handful of these really add to our knowledge of the subject.

An example of a useful study is one which was carried out by some English workers who studied 5,000 children born in different communities in the same year. The communities were classified according to the average amount of sulphur dioxide in the atmosphere. The children were observed for fifteen years to determine whether differences in respiratory disease rates could be recognized. Some valuable points were established, but even so thorough a study as this ran into difficulties. During the lengthy period of study changes occurred in fuel usage, and this affected sulphur dioxide (SO_2) levels. New methods of measuring SO_2 came into use and the reliability of the old method was questioned.

Nevertheless, some valuable information was obtained. It was found that increased exposure to polluted air, as indicated by SO_2 concentration, was associated with increased incidence of lower respiratory disease - chiefly pneumonia and bronchitis. The effect was much more marked in families of low socio-economic status. Bronchitis in children is fairly common in Britain, in contrast to Canada where it is relatively unusual.

What Diseases are Caused by Air Pollution?

This is the question we would most like to be able to answer definitively. For the present we can only say that certain occupational diseases, such as silicosis and asbestosis, are quite clearly related to the inhalation of toxic substances, and that a large proportion of chronic respiratory disease and lung cancer can be blamed on cigarette smoking. Polluted community air seems to play an enhancing effect in these latter conditions but, to date, this is very difficult to quantify.

We can say that chronic bronchitis, lung cancer and some forms of emphysema are considerably more common in city dwellers than in people who live in the country. There is a great temptation to take this as evidence that air pollution is the cause, but there are a number of reasons why we should be cautious about this conclusion.

One of them is that the above-mentioned difference between urban and rural populations is much less noticeable in females than in males. Another point is that, although these diseases remain more common in the cities, the rate of increase is just as obvious among country people. It could be argued that this means that pollution is extending into the country, but this is not borne out by atmospheric surveys. In fact, even in the cities many of the pollutants which are regularly monitored have been decreasing in recent years.

Another problem is that most of our information about the prevalence of diseases is derived from mortality (death statistics), rather than from any exact knowledge of the occurrence of diseases. The reason for this is that a "cause of death" must be recorded on every death certificate while there is no comparable record of sickness.

Estimates of the prevalence of a disease are just that - estimates. The fact that a particular doctor or hospital encounters a certain amount of a given disease is not an accurate indication of how common it is in the population. Some diseases rarely cause death, so they may really be more common in the community than the death records indicate. Other diseases, such as heart failure and pneumonia are common causes of death and so may be unduly emphasized in mortality figures.

These are some of the difficulties one encounters in trying to establish the effects of air pollution.

Conclusions

1. There is no doubt that people with chronic respiratory diseases are adversely affected by some kinds of air pollution.

2. Some respiratory diseases are caused by the more intense forms of air pollution - tobacco smoking and occupational exposures.

3. Community air pollution may be the cause of some respiratory diseases. There is also a possibility that the inhalation of trace amounts of metals and other chemicals from the air may contribute to other chronic and degenerative diseases, which are generally on the increase.

What about the future?

The foregoing description of what is known about the effects of air pollution on health is a very "middle of the road" approach. Some medical authors have gone so far as to imply that half of all human illness can be attributed to air pollution. Others, just as well-qualified, say that there is no evidence that air pollution causes any illness.

It is apparent that much more information is needed before a consensus can be reached.

Obviously, one cannot wait for clear proof of harmful effects before deciding to curtail air pollution. The most logical approach is to restrict contamination of the air by substances which are known to be harmful in other contexts, i.e. in occupational exposure or laboratory experiments.

Some of the problems inherent in studying the effects of air pollution have been mentioned. It appears that the best information comes from statistical studies which in turn depend on good medical records. Some comprehensive health insurance schemes now maintain life-long health records of individuals and it may be from such sources that further knowledge will come. Records which are kept for "medicare" programs are also becoming increasingly valuable for statistical purposes.

In general, epidemiologists believe that careful long term studies will eventually reveal the more subtle ways in which our health and longevity are affected, not only by air pollution, but by other environmental factors as well.

This is the best justification we have for demanding good environmental management now - to protect us against those adverse effects which may not yet be fully appreciated.

In Ontario, we are fortunate in having an efficient and rapidly developing air management system. In the few years since the province took over this function, great progress has been made both in identifying sources of pollution and in beginning to bring them under control. Obviously, there is no room for complacency about this situation -- too much remains still to be done -- but, with the progress that has already been made, we are justified in looking to the future with optimism.

APPENDIX I

GLOSSARY

1) *Air Pollution* - the presence in the air of any substance or mixture of substances in such concentration that they may have a harmful effect on people, animals, vegetation or structures.

2) *Ambient Air* - the surrounding air, that which we breathe.

3) *Micron* - a unit of measurement, one-thousandth of a millimetre or about a twenty-five thousandth of an inch.

4) *Occupational Disease* - a disease which characteristically occurs in workers with a particular occupation or in a particular industry.

5) *ppm* - parts per million

APPENDIX II

EFFECTS OF INDIVIDUAL POLLUTANTS

Carbon Monoxide (CO)

This is a toxic gas which is produced when carbon-containing materials are burned in an oxygen-deficient environment. (When there is ample oxygen, the relatively harmless carbon dioxide is produced.) Carbon monoxide acts by attaching itself to the hemoglobin in the blood and interfering with the collection and distribution of oxygen.

The amount of CO in the blood depends not only on how much there is in the air, but also on how long the person breathes it and how active he is at the time (as this affects breathing rate and depth). An amount that would not bother a sedentary person could cause headache and dizziness in a hardworking man in one hour.

While the poisonous effect of high concentrations (e.g.500 ppm or more) has been known for years, there is still no agreement on whether prolonged exposure to low levels may also cause ill health. The concentration on city streets may vary from 1 to 50 parts per million (occasionally even higher) depending on the amount of automotive traffic.

Even in the absence of recognizable long-term health effects, some researchers have demonstrated short-term effects on vision, hearing and mental ability at relatively low concentrations of CO.

People who smoke cigarettes expose themselves to CO concentrations far higher than those on a busy street. Smoking and vehicle exhaust are additive factors in CO exposure. The elimination or reduction of both these sources is highly desirable for human health.

Hydrocarbons and other organic chemical compounds

At any given time the air contains a large variety of organic compounds of various degrees of complexity. These are derived from industry, transportation and heating sources and even from natural causes such as decaying vegetation. Some of them have known physiological effects on man, animals or plants, including the ability to produce cancer in certain laboratory animals. Others are identified but their effects are not known.

Some physicians believe that these chemicals can make man more susceptible to certain allergic substances. Some think that the excess deaths from respiratory diseases (including lung cancer), which occur in cities, must be caused by them. On the other hand, many of these compounds are less common now than when coal was more widely used as a fuel. The real reason for the continuing increase in respiratory disease - other than that portion resulting from cigarette smoking - is not known.

Oxides of Nitrogen

Nitrogen makes up about 80% of the air around us. When anything burns at high temperature there is a good chance that some nitrogen will combine with oxygen in one of a number of possible proportions. The most common compound of this group is nitrogen dioxide (NO_2). Like SO_2, it can act as a pulmonary irritant at higher concentrations and may possibly do so at the low concentrations at which it occurs in community air.

In southern latitudes, NO_2 may react with hydrocarbons (e.g. from fossil fuels) under the influence of ultraviolet radiation, to produce the irritating aldehydes and oxidants which are characteristic of photochemical smog.

Particulate Matter

By convention, this term is restricted to solid or liquid particles which are small enough to remain suspended in the air. The tendency of a particle to settle out of the air is largely a function of its size. For the most part, only particles under 40 microns in diameter remain suspended and can be breathed in. The normal filtration system of the human respiratory system (hairs, air passages, mucus) remove most particles over 5 microns in diameter. Only those below this size get into the lungs.

These particles may be retained or exhaled again. Those which are retained may be quite inactive, may exert a local irritant effect, or may be dissolved and absorbed into the blood stream and carried to other parts of the body.

Many people believe that gases like SO_2 and nitrogen dioxide are more likely to be carried deep into the lung recesses if they are first adsorbed onto some sort of particulate matter. This may explain why the expected effects of polluted air are often not achieved during laboratory experiments when pure gases are tested. Remember that "particulate matter" is a very non-specific term, unless one knows the composition and size of the particles.

Sulphur Dioxide (SO_2)

When a sulphur-containing fuel such as coal or oil is burned, one of

the end products is sulphur dioxide gas. As a result, this material can be identified in the ambient air of most communities. In the neighbourhood of smelters where sulphur-containing ores are roasted, the concentration of SO_2 can be quite high at times. SO_2 also occurs in discharge gases from incinerators, some pulp plants, and a number of other industries.

In the air, SO_2 can be converted to sulphuric acid or to its salts (sulphates). Because these compounds are commonly found in polluted air, and because they are relatively easy to measure, it is not unusual for people to equate the effect of polluted air with its SO_2 content.

Many studies of the health effects of polluted air refer to the SO_2 content of the air, but in most cases the authors state that SO_2 should be taken only as an "index" of pollution rather than as being responsible for the effects. In Ontario, the pollution index published for several cities is based on two constituents of polluted air - SO_2 and particulate matter. When the concentration of these two increases, one can assume that other pollutants are also increasing and/ or that the weather conditions which usually disperse pollution are inoperative.

In experiments with laboratory animals it requires concentrations of SO_2 considerably higher than those encountered in ambient air to produce effects. A partial explanation is contained in the note on "particulate matter".

Trace Substances

Many chemical elements find their way into the air, either by a natural process or as a result of man's activities. The term "trace substance" indicates that they usually occur in very low concentrations.

Some have been of particular concern - cadmium, fluorine, lead and mercury. There are many others, any one of which may claim attention in the future. Other substances, such as asbestos and silica, are also of concern because they are infamous as causes of occupational disease. At various times it has been suggested that some of these - particularly asbestos, fluorine and lead - could pose a community as well as an occupational hazard. Recent reviews suggest that, at least for the present, neither asbestos nor fluorine is a problem in this sense.

The significance of lead as a potential community problem remains somewhat undecided. The amount of lead in the air may not in itself be too serious, but much of it settles on the ground and, in certain circumstances, gets into the food chain. At present, indications are that a problem could develop in the future, and that attempts should be made to reduce the amount of lead being added to the environment.

This may eventually lead to a decision to ban the use of tetra-ethyl lead in gasoline, although there is the problem that many of the cars now on the road require premium or high octane fuel.

To continue giving satisfactory performance on unleaded gasoline, such cars require the addition of aromatic hydrocarbons to the fuel, and such additions may increase hydrocarbon emissions from the tail pipe.

APPENDIX III

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These are only a few of hundreds of reference works on this subject. Interested students will find many sources of information in school or university libraries, or in those of the appropriate government departments.

APPENDIX IV

STATISTICAL INFORMATION

The accompanying graphs are intended to give some idea of the changes which are occurring in deaths from lung cancer and chronic respiratory disease, and at the same time to point out some of the pitfalls of statistical interpretation.

All statistics are imperfect and graphs can be manipulated to give unreliable information.

The graphs shown here could be considerably changed in appearance and in the effect they convey by making them wider or narrower, i.e. by using a different scale or a different overall size. For example, the graphs for males and females are on a different scale-- the "rate" numbers along the sides indicate it is. The reason for this is that the number of males dying of lung cancer and chronic respiratory disease is several times that of females. If put on the same scale, the female lines would be so close together as to make reading difficult.

The graphs deal with two internationally accepted categories of disease.

'Respiratory cancer' if officially 'cancer of trachea, bronchus and lung'. As the vast majority of these are cancer of the lung, the graphs can quite properly be considered to show what is happening to lung cancer in Ontario. Since most people with lung cancer die of their disease, these figures also reflect the "prevalence" of lung cancer.

'Chronic respiratory disease' refers essentially to two official categories: 'Chronic bronchitis, emphysema and asthma' and 'other respiratory disease' - the group that is left when all easily classifiable diagnoses are removed.

The three lines represent:

Ontario - average experience for the whole province.

Cities - a composite rate for the metropolitan areas of Hamilton, London, Ottawa, Toronto and Windsor.

Rural - a composite rate for the rural component of several counties.

Immediately we see the possibility of 'author's influence' on the statistics, as there is no assurance that the selected groups are fully characteristic of all city vs. all country dwellers.

Also, the rates are based on the portion of the population 'aged 35 and over'. This is probably quite valid for 'respiratory cancer', as very few people die of these diseases below the age of 35. However, the case of 'chronic respiratory diseases' is somewhat different, since here as well all the deaths which occurred in the province in this category of diseases have been charged against the portion of the population aged 35 and over. This has been done for convenience, but if we were to separate out those who died under age 35 the rates for chronic respiratory disease would be somewhat less than those shown in these graphs.

Next, we come to the question of interpretation. Ideally, the reader should have the actual figures (the 'raw' data) and should be allowed to make his own deductions.

The graphs are meant to summarize the information but, as cautioned above, could also be used to influence the reader in his interpretation.

A few reliable observations can be made:

a) In males, many more die from lung cancer than from chronic respiratory disease, and this is true even in the country.

b) In females there is also a difference, but it is much less obvious.

c) In both of these disease categories the number of male deaths is much higher than among females.

d) Generally, the death rates in cities from these diseases are higher than the provincial averages. The country rates are usually below the provincial rate. This is very obvious in the male cancer graph, less so in the others.

e) All of these diseases are on the increase.

f) The rate of increase (as represented by the angle of the graph) is about the same in the country as in the city, although the city rates remain higher.

Other deductions can be made from these graphs. It is left to the reader to decide whether or not this information is consistent with the theory that air pollution contributes to these diseases.

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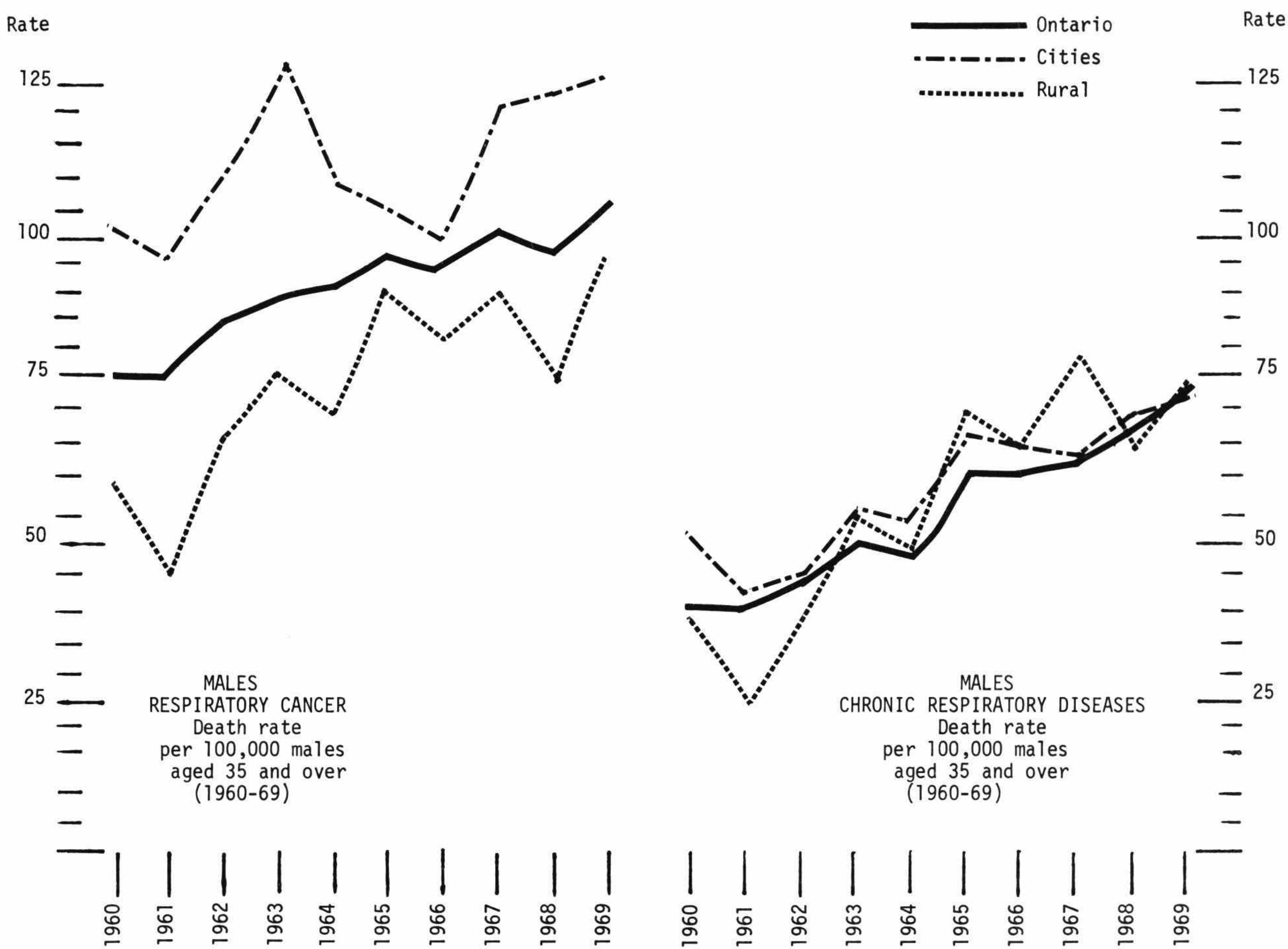
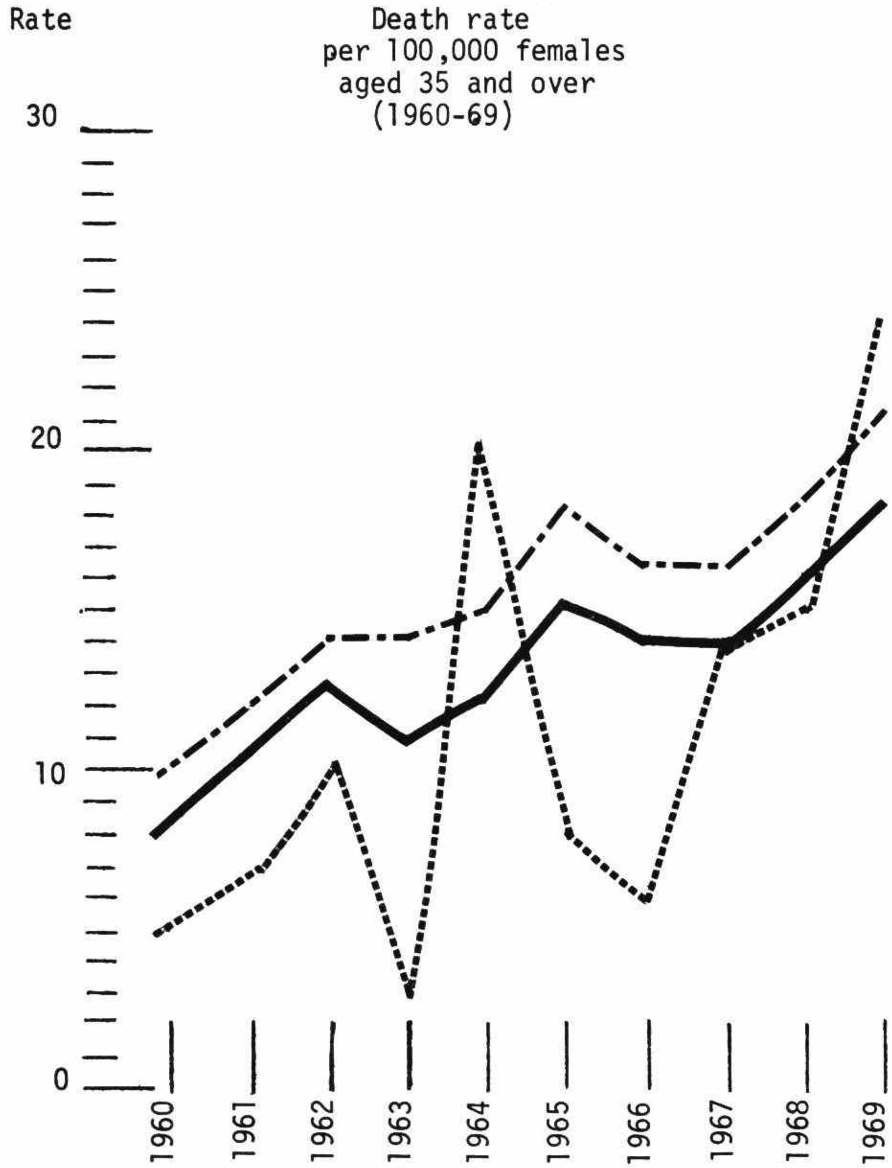
Death Rates per 100,000 in Ontario residents, aged 35 and over from Respiratory Cancer and Chronic Respiratory Disease, in the years 1960-69.

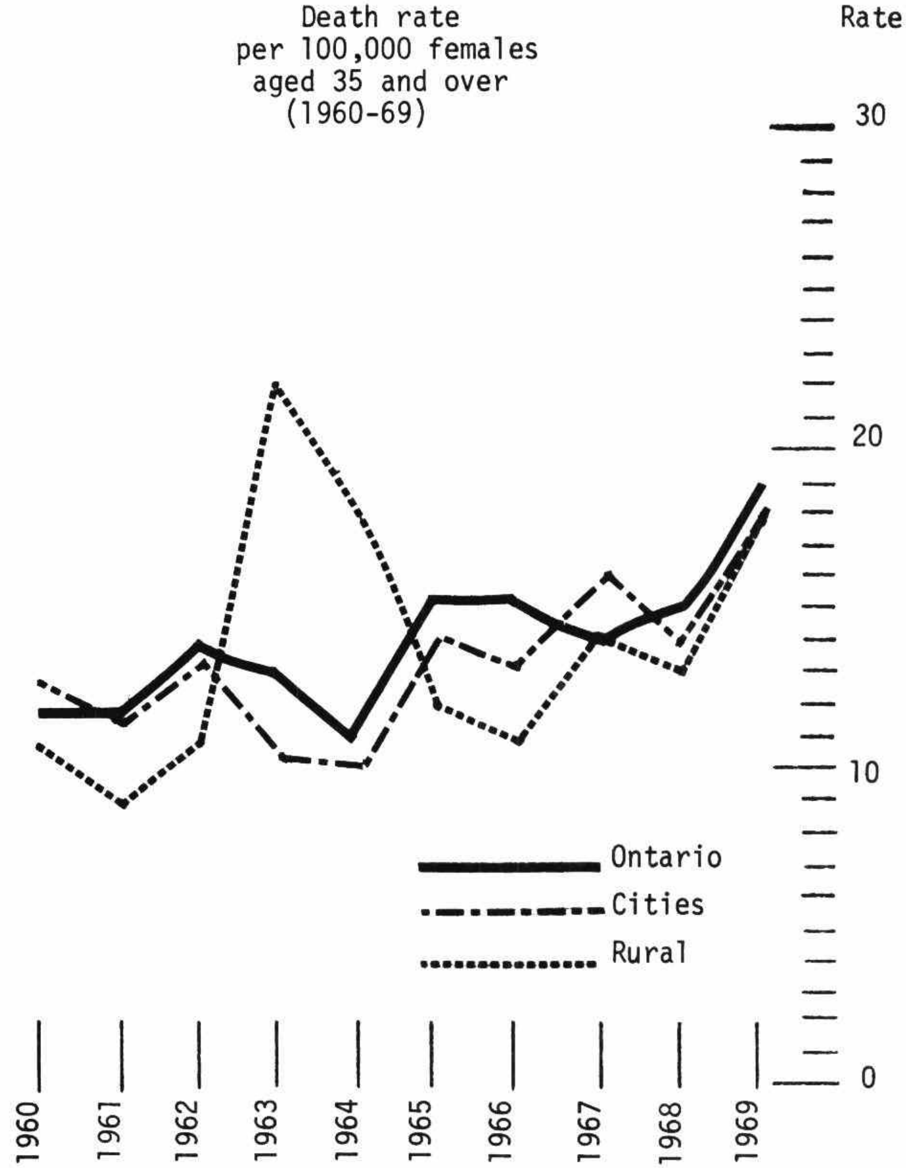
RESPIRATORY CANCER				CHRONIC RESPIRATORY DISEASE		
- MALES -						
ONTARIO	CITIES	RURAL		ONTARIO	CITIES	RURAL
75	102	58	1960	41	52	38
75	96	45	1961	41	43	25
84	111	66	1962	44	45	39
87	132	76	1963	51	57	57
89	111	68	1964	50	55	51
97	104	90	1965	62	67	69
92	96	82	1966	62	65	66
102	122	91	1967	63	64	80
99	123	74	1968	67	69	65
108	125	95	1969	73	72	74
- FEMALES -						
ONTARIO	CITIES	RURAL		ONTARIO	CITIES	RURAL
8	10	5	1960	12	13	11
10	12	7	1961	12	12	9
12	14	10	1962	14	13	12
11	14	3	1963	13	10	22
12	15	20	1964	11	10	18
15	18	8	1965	15	14	12
14	16	6	1966	15	13	11
14	16	14	1967	14	16	14
15	18	15	1968	15	14	13
18	21	24	1969	19	18	18


Rate
125
100
75
50
25
Ontario
Cities
Rural
MALES
RESPIRATORY CANCER
Death rate
per 100,000 males
aged 35 and over
(1960-69)
MALES
CHRONIC RESPIRATORY DISEASES
Death rate
per 100,000 males
aged 35 and over
(1960-69)
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969

FEMALES
RESPIRATORY CANCER
Death rate
per 100,000 females
aged 35 and over
(1960-69)



FEMALES
CHRONIC RESPIRATORY DISEASES
Death rate
per 100,000 females
aged 35 and over
(1960-69)



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